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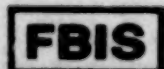
4 March 1980

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EARTH SCIENCES

No. 4

Scientific Activity in Oceanography



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4 March 1980

USSR REPORT EARTH SCIENCES

No. 4

SCIENTIFIC ACTIVITY IN OCEANOGRAPHY

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Annotation

[Text] This report was presented to the International Association of Physical Sciences of the Ocean at the 17th General Assembly of the International Geodetics and Geophysics Union.

Introduction

This report includes brief information on the most important results of theoretical, expeditionary and experimental studies on the field of the physical and geographic problems of the world ocean during the 175-1978 period by the separate collectives of oceanologists of the Soviet Union.

The bibliography of this report was compiled only from the most important publications on the indicated problems (the monographs, the collections of articles and the atlases of maps).

INSTITUTE OF OCEANOLOGY IMENI P. P. SHIRSHOV OF THE USSR ACADEMY OF SCIENCE

Studies of Mesoscale Variability of the Dynamics of the Ocean

1. Study of Synoptic Ocean Eddies

In 1977-1978 the Institute of Oceanology performed studies of the space-time variability of the basic hydrophysical fields of the ocean in the southwestern part of the Atlantic Ocean (the current speed, density, water temperature). The studies were performed over the course of a year in the hydrophysics test area POLYMODE especially equipped with buoy stations (19 stations).

The studies by the POLYMODE program were performed within the framework of the Soviet-American Agreement on Cooperation in the Study of the World Ocean signed in Washington in 1973.

The POLYMODE program provided for the following:

a) the performance of the hydrophysics experiment of a year's duration in the Atlantic Ocean (the Sargassus Sea) to study the structure, kinematics and dynamics of synoptic eddies, their interaction with each other and with movements of other scales (the average currents, the internal waves, turbulence):

b) the performance of theoretical studies aimed at the development of physical-mathematical models of the ocean synoptic eddy field and the creation of numerical methods of calculating nonstationary currents in the ocean taken into account the existence of the eddies.

The Soviet research with respect to the POLYMODE program were started in 1976, and they continued to the present time. The experimental part of the program was carried out during the period from July 1977 to September 1978. The studies were performed on a hydrophysical test area 300×300 nautical miles (about 300,000 square miles) in which 19 autonomous buoy stations (ABS) operated continuously for a year with the current and temperature pen recorders. During performance of the experiment, the following projects were carried out.

a) five expeditionary trips of the research vessels of the Oceanology Institute were made in the vicinity of the POLYMODE test area with a total duration of more than 1.5 ship-years;

b) the ships of the interdepartmental expedition performed 17 large-scale quasisynchronous density surveys (300 × 300 miles), 14 mesoscale surveys (the vicinity of the buoy test area) and 7 microsurveys (the study of the structure of the individual eddies);

The preliminary analysis of the given measurements demonstrated the following:

a) during the time of operation in the POLYMODE test area, the passage of 21 eddies of a synoptic scale and several tens of smaller deformations was recorded by instruments. The synoptic eddies have horizontal dimensions from 150 to 300-400 km, and they moved to the west at a speed from 3 to 10 km/day. The eddies were traced to depths of 304 km;

b) the movement of the water in the eddies causes significant meridional exchange in the formation in the upper layer of the ocean of temperature fronts with a temperature gradient of 0.1-0.2° per kilometer. The frontal sections were also observed between the eddies;

c) the biological and hydrochemical measurements demonstrated the significant nonuniformity of concentration of the biogenic elements and productivity of the upper layer connected with the synoptic eddies. In the region of cyclonic eddies the productivity turned out to be maximal, and in the region of the wake of an ocean cyclone, an increase in the number of organisms of the first links of the food chain was observed;

d) the intensification of vertical movements in the synoptic eddies indicates the possibility of the development in the regions of their passage of super-deep convection, consideration of which has significant practical significance.

The expeditionary part of this Soviet section of the POLYMODE program was completely carried out. Unique materials were obtained from the long measurements of different hydrophysical parameters over a large body of water which will serve as the basis for further studies of the dynamics of the synoptic eddies and their role in the general water circulation of the world ocean.

Studies of the Variability of the Equatorial Currents of the Indian and Atlantic Oceans

In 1975-1976, the scientific research ship "Akademik Vernadskiy" on the 10th and 11th trips and the scientific research ship "Akademik Kurchatov" on the 22nd trip performed multiple measurements of the equatorial currents during the winter and summer periods. A comparison of these measurements with the data of preceding studies demonstrated that the large-scale features of

the vertical structure of the system of equatorial currents of the Indian Ocean have significant stability. It was discovered that the most stable flow in this system is the Tareyev current -- the analog of the equatorial subsurface countercurrents existing in the Pacific and Atlantic Oceans. The observations in the Indian Ocean demonstrated that during the summer in the Northern Hemisphere the Tareyev current is maintained in the form of a subsurface core of maximum velocity in the common eastern equatorial transfer excited by the southwestern monsoon. It was discovered that the characteristic features of the spatial structure of the equatorial circulation of the water of the Indian Ocean is a significant increase in the current velocity in the upper layer on moving from the east to the west. In the winter period, the Mussonnoye current takes up the fine surface layer which in the western part of the ocean amounts to a total of about tens of meters. The Tareyev current and the Equatorial Countercurrent formed from this region a united system of each of the transfer of water to the Indian Ocean having multicore structure.

In the Atlantic Ocean the measurements of the equatorial subsurface Lomonosov current were taken during the international expedition of the ATEP. By the measurement data a study was made of the average conditions of ocean circulation in the tropical Atlantic and its low-frequency variability. The data from the instrument measurements made it possible to construct a generalized diagram of the currents on the meridional cross section of the ocean through $23^{\circ}30'e$. The average flow rates of the northern and southern equatorial countercurrent in the Atlantic Ocean and the Lomonosov current have been estimated. Along with the inertial and the semidiurnal tidal fluctuations of the currents, 3-4-day fluctuations of them had been discovered which reflect the reaction of the ocean to the forcing atmospheric disturbances. A clear instrument confirmation of the meandering of the Lomonosov current was obtained, and the time-space characteristics of this phenomenon were determined. The meandering of the Lomonosov current causes rearrangement of the accompanying oceanological field, and it is the defining factor of their synoptic variability at the thermocline depths. It was demonstrated that the appearance and disappearance of the westerly intermediate equatorial current is connected with variations of the zonal pressure gradient at the equator.

Theoretical and Model Studies of the Dynamics of the Ocean

1. Study of the Dynamics of Large-scale Nonperiodic Currents in the Baroclinic Oceans.

Numerical models have been developed, and calculations have been made of the temperature and current fields of the world ocean with five-degree steps horizontally. The temperature fields obtained reflect the basic peculiarities of the distribution of the water masses and the large-scale circulation of the world ocean well. In the upper horizons of the ocean the vertical current field correlates well with the basic "centers of action" of the ocean -- the large-scale steady cyclonic and anticyclonic formations.

In the example of the northern part of the Atlantic Ocean a study was made of the process of the formation of large scale circulation in the baroclinic ocean under the effect of wind and heat exchange. It was demonstrated that the heat exchange plays a very important role in this process. The gradient currents of purely wind origin are small, but the indirect effect of the wind by redistribution of the density field is highly significant.

The diagnostic calculations of the horizontal and vertical currents of the world ocean and its individual bodies of water with a one-degree stepsize horizontally have been performed.

A special nonlinear numerical model has been developed for calculating the equatorial currents. The calculations of the equatorial subsurface currents of the Atlantic Ocean (the Lomonosov current) have been made by this model.

2. Study of the Dynamics of the Synoptic-Scale Eddies.

On the basis of the observation data from the "Poligon-70" [Polygon-70] expedition, the presence of synoptic-scale eddies was discovered, and basic parameters of the eddy field were found. A conclusion was drawn that the developed ocean eddies correspond satisfactorily to the linear baroclinic Rossby waves, and the movement of the water in the eddies is horizontally divergent. The universality of the phenomenon of synoptic eddy formation is demonstrated, and it was established that the eddies contain a significant portion of the kinetic energy of the ocean. On the basis of the data from measuring the currents during the POLYMODE experiment, the problems of the energetics of eddies were investigated.

The first nonlinear eddy-resolving model in the USSR was developed. A computer was used to calculate the process of the occurrence of the development and growth (in the statistical sense) of eddy (horizontal and vertical) currents and the temperature field for five levels. The process of the energy exchange between the eddies and the large-scale movement was investigated.

Together with the co-workers of the MGI Institute of the Ukrainian SSR Academy of Sciences, a dynamic-stochastic method of calculating density fields and eddy currents was developed. The time-space variations of the eddies were calculated by this method and on the basis of several hydrologic surveys performed during the POLYMODE expedition. It was shown that the calculated eddy velocities agree well with the measurement data.

3. Study of Circulation in Individual Seas.

Together with the scientists from the Polish People's Republic, the first calculations were made of circulation in the Baltic Sea. Together with the scientists from the People's Republic of Bulgaria and Romania, studies were made of the hydrologic and hydrochemical characteristics of the water in the Black Sea.

4. Nonlinear Rossby Waves.

The construction of two-dimensional separated barotropic Rossby waves as a possible model of synoptic eddies or Gulf Stream eddies is an important result. Two models were constructed: the asymptotic theory of an almost axisymmetric soliton and the exact solution of the basic equations having a singularity in the derivative of the vorticity. The stability of the last solution is demonstrated. Important results were also obtained in the nonlinear theory of topographic Rossby waves. A general theory of nonlinear barotropic waves over a cylindrical rough bottom was constructed.

5. General Theory of Small Oscillations in the Ocean

Asymptotic formulas were constructed, and on the basis of them numerical calculations of the dispersion relations were performed for different types of waves on a sphere. Studies were made of the cases with different relations between the latitudinal and longitudinal wave numbers. A study was made of the effect of the horizontal component of the vector of the angular velocity of rotation of the earth on the low-frequency waves.

6. Problem of Thermal and Dynamic Interaction of the Atmosphere with the Upper Layer of the Ocean.

A nonstationary, uniform model was constructed for calculating the thickness and the temperature of the upper uniform layer, thickness and temperature gradient in the seasonal thermocline and also turbulent heat fluxes at the interfaces of these layers. A simple parameterization of the mixing processes was proposed based on analyzing the results of the laboratory experiments.

7. Theoretical Model of the Geodynamo.

A quasigeostrophic model of a geodynamo was constructed, the two-level spectral equations were obtained having two quadratic integrals of motion. A schematic is proposed for the currents in the liquid core of the earth agreeing qualitatively with the tectonic data and observations of the earth's magnetic field. The nondissipative mesoscale currents in the core satisfying the boundary conditions of nonpassage without the formation of boundary layers.

Marine Turbulence

The basic areas of research were the study of small-scale ocean turbulence during the processes of diffusion of admixtures in the sea. Studies were made simultaneously of the background hydrometeorological processes of determining the turbulence laws, in particular, the fine structure of the hydrophysical fields, internal waves and certain peculiarities of the interaction of the ocean and atmosphere.

Field measurements were taken with respect to the indicated problems on special trips or by special details on the scientific research ships and also on the joint international expeditions of the CEMA countries on the problem of the world ocean. The measurements in the ocean were performed by new sets of measuring instruments especially constructed for the indicated purposes with sensitive sensors for measuring the velocity pulsations, electrical conductivity and temperature and also sensors for measuring the average values of these parameters.

The measurements of the turbulence and the background hydrometeorological processes were taken in the typical regions (test areas) with respect to average hydrometeorological conditions in the Pacific, Atlantic and Indian Oceans.

When analyzing the collected data, primary attention was given to discovering the mechanisms of the generation of turbulence and also the dependence of its characteristics on the defining background conditions. It was discovered that the turbulence regime in the scale intervals from several meters to millimeters can be different depending on the defining parameters. On generation of turbulence by the breaking of internal waves, the external scale of the turbulence can be small, which leads to smallness of the Reynolds number and to nondevelopment of the turbulence. In this case it is possible to have no clearly expressed sections of satisfaction of the universal power laws of the theory of locally isotropic turbulence. The turbulence distribution with respect to wave numbers (the scales of the movements) vary as a function of the predominance of certain forces (buoyancy, inertial, viscosity) in the given scale interval. In the stratified ocean with respect to density, the turbulence frequently develops in this layers and exists in the form of individual spots. The boundaries between the inertial-convective, viscous-convective, viscous-diffusion interval and the buoyancy interval for ocean turbulence are mobile and are basically determined by the values of the mean current velocity gradients and the density of the water in the vicinity of the measurements. The distribution of the sizes of the turbulence spots and also the dissipation rates of the turbulent energy in them is described in the majority of cases by a logarithmically normal law. The diffusion of the spots and the stream of admixture in the sea are not always described by the expressions of the idealized turbulence theories. In particular, in the coastal zone of the sea an important role in the spread of an admixture is played by advective factors and the current velocity gradients, which leads to preference in this zone for the advective-diffusion models of the phenomenon. The spectrum of concentration pulsations of admixture is significantly influenced by the processes of breakdown of the cloud of admixture into parts caused by the interfering internal waves or Langmuir cells. The probability distribution law of the admixture concentration pulsations in the upper layers of the sea is in the majority of cases close to logarithmically normal.

Experimental Study of Thermohalinic Processes in the Ocean

In 1975-1978 preparations were made for laboratory studies that were performed on the processes of heat and mass transfer in the boundary layer in the water at the water-air interface. A study was made of the conditions of formation and the existence of a thin thermal layer at the surface of the water and also its structure under the conditions of free and forced convection. The role of salinization of the thin surface layer on evaporation of the water in the transport processes in the boundary layer was discovered. It was demonstrated that at a temperature of 20-30° C the defining factor in the development of thermohalinic instability is cooling. A study was made of the mechanism of the development of penetrating convection in a stably stratified liquid cooled from the free surface. A study was made of the phenomenon of collapse of uniform spots in the continuously stratified body of liquid which is responsible for the formation of layered structures in the destruction of turbulence, and obviously explains the ubiquitous propagation in the ocean of the thin thermohalinic structure.

Important differences were found in the statistical characteristics of the thin vertical thermohalinic structure of the frontal regions and the regions of intense horizontal advection and the fine structure of the relatively quiet areas with slightly varying stable stratification. New data were obtained on the thin thermohalinic stratification of the water of the Sargaseus Sea and its interaction with the propagation of the Mediterranean water in the Atlantic Ocean, the fronts and synoptic eddies.

A study was made of the structure of the fronts in the Sargaseous Sea and the mechanism of their formation by synoptic ocean fronts. A numerical model was created of frontogenesis by the deformation field of the movement.

A study was made of the role of the processes in the formation of horizontal, mesoscale nonuniformity of the temperature and the salinity in the upper cross uniform layer of the ocean. A summary spectrum of the variability of the surface temperature of the ocean was constructed.

The concept of the mechanism of formation of the thermocline in the ocean as a consequence of heat transfer from the equatorial regions to polar regions was developed.

The second and third steps in the Soviet-American experiment were performed by synchronous measurements of the surface temperature of the ocean from the NOAA satellites (the United States) and onboard the scientific research ship "Akademik Kurchatov" in the Indian Ocean and Gulf Stream.

A study was made of the kinematic effect produced by the random internal wave field on the surface of the ocean and its role in the transport of a passive admixture.

A study was made of the influence of the thermodynamic effects caused by the gravitational field on the distribution of individual elements in the ocean.

Models of the transport of radioactive traces in the ocean and methods of estimating the transport parameters were developed. A complete survey was made of the transport parameters in the ocean determined by the radioactive isotope distributions.

In practice all known characteristics and properties of seawater have been gathered, analyzed and classified in the reference manual from observation materials, laboratory experiments and theoretical calculations.

Hydrologic Studies of the Inland Seas

Broad oceanographic studies have been made of the Mediterranean Sea: the water balance of the sea and the water exchange through its primary straits, the thermohalinic structure of water and the mixing processes, circulation of the water and the vertical structure of the currents.

The current measurements from a stabilized buoy on the Black Sea shelf have continued for about 3 years. These measurements have been accompanied already for more than a year also by observations of the water temperature.

The experiments of the joint Soviet-Bulgarian expedition (1976) obtained new data on water circulation of the shelf of the western part of the Black Sea. The recorded anomalously large current velocities in the bottom (up to 1.3 m/sec) and surface (to 1.5 m/sec) layers made it possible to explain the mechanism of southwest transport of the terrigenous material brought in by the Danube.

Hydrochemical Studies

The basic results of the studies are reflected in the monograph "Chemistry of Ocean Water," in which the laws of the distribution of the elements of the carbonate system, the main biogenic elements, dissolved gases and organic matter in the waters of the entire world ocean are generalized. The chemical-oceanographic division of the water into districts is presented, the limits of variability of the hydrochemical characteristics under the effect of physio, biological and chemical processes in the various layers of the ocean are established; approximate estimates of the annual scales of the incoming and outgoing components of the circulation and the oxygen balance, the biogenic elements and salts in the world ocean are presented.

The many years of observations of various expeditions in the form of maps and sections with respect to basic hydrochemical indexes presented in the "Hydrochemistry" divisions of the ocean atlases are generalized.

An analysis was made of the interyear, seasonal, mesoscale and fine scale variability of the basic hydrochemical parameters in four structural zones for polar, temperate, subtropical and tropical latitudes of the world ocean, demonstrating that the interyear chemical variability in the regions of encounter of water of different origin can be manifested at all depths of the ocean, and the mesoscale and fine scale fluctuations of the composition

of the water have a significant influence on the magnitude of the primary production in the tropical and subtropical regions.

The expeditionary studies of the dynamics of the hydrochemical structure of the northwestern part of the Indian Ocean demonstrated that the intermediate and deep water of this region to the north of 1.5° south latitude became richer in oxygen and impoverished with respect to phosphates by comparison with the preceding years.

The studies by the POLYMODE program discovered the great variability of the hydrochemical fields under the effect of synoptic eddies in the ocean.

Laboratory simulation of the process of vertical transport of the components of the salt composition in the stratified seawater was carried out demonstrating that for the case of penetrating convection the generation rate of the nonuniformities of the inert admixture in the vicinity of the upper boundary of the thermocline is significantly higher than the molecular and turbulent diffusion rate. This explains the high rate of vertical transport of some of the chemical properties of the water in another way.

Chemistry of Bottom Sediments

The studies have encompassed not only the main components of the sediments -- the sediment forming elements -- but also a large number of trace elements. The studies encompassed both the solid phase of the sediments and water, the water impregnating them -- the interstitial water, and a study was also made of the distribution of the interesting elements in the water above the bottom. In order to realize the indicated studies, the old methods of chemical and physical-chemical analysis have been constantly improved and new ones have been developed inasmuch as for the indicated purposes, considering the complexity of the composition of the subsequent material, great selectivity and accuracy of the methods were required.

The principles of the theory of chemical processes of diagenesis of modern bottom deposits have been developed. Two types of diagenesis have been isolated -- oxidizing and reducing. The steps (stages) of chemical conversions of the elements and material composition in diagenesis have been established.

The first chemical profile of the sediments of the Pacific Ocean has been created. The profile begins off the coast of Japan, it intersects the Hawaiian volcanic center and ends off the Mexican coast. The profile is in the form of 50 columns of sediments of different lithologic-facies types. When investigating the profile, the distribution laws in the ocean sediments of about 40 chemical elements were studied, including the behavior of them in the diagenetic processes.

Study of Biogeochemical Cycles of Materials in the World Ocean, their Variation as a Result of the Activity of Man

The basic principles of the study of the general circulation and transformations of the carbon compounds in the seas and oceans have been developed (their composition includes the basic mass of anthropogenic contamination), and a methodology for systematic studies and a broad set of analytical methods were also found. As a result, new quantitative estimates have been given for the elements of the organic carbon balance. A geochemical model was constructed for the carbon cycle in the world ocean. An empirical law was derived for the relations of the elements making the transition from the ocean to the atmosphere. The most important changes in composition of organic material and the fate of the classes of compounds making it up in the stage of sedimentogenesis and diagenesis were discovered. In the last two years the materials of several thousand analyses have been used to construct a new map of the distribution of organic matter in the sediments of the world ocean; the location of its absolute masses and also the facies and regions favorable for accumulation of organic matter, the parent substance for oil and gas, have been established.

Numerous maps, diagrams, and schematics reflecting the discovered distribution laws in the world ocean of lipids, carbohydrates, humic acids, humins and other bottom geopolymers have been constructed and published.

Systematic biogeochemical studies have been made of the pollution of the mouths of rivers and the pre-estuary bodies of water of the southern seas of the USSR and Baltic Sea.

Seismic Studies

In the various seas and oceans in the expeditionary work seismic studies have been made of the earth's crust and the upper mantle having great significance in the solution of geological problems.

In the Indian Ocean (58th trip of the scientific research ship "Vityaz") -- on the east Indian ridge, the adjacent basins and the Zondskiy trench. New data have been obtained on the structure of these regions important for comparative study of the tectonics and the geological history of the ridges, basins, deep-sea trenches and the nature of their salinization.

In the central Atlantic and the southeastern part of the Pacific Ocean (24th trip of the scientific research ship "Akademik Kurchatov") studies have been made of the rift zones and the transform faults, including the eastern continuation of the Atlantis fault. New information has been obtained on the structure and the thickness of the sedimentary cover and the earth's crust, the relief of the acoustic basement, and the tectonics of the investigated regions.

Studies have been made in Lake Baykal. Data have been obtained for the first time on the thickness and structure of the sedimentary cover of

various parts of the lake, the velocity characteristic of the upper part of the earth's crust.

Studies have been made (23rd trip of the scientific research ship "Akademik Kurchatov") in the Barents Sea to study the geological structure of the Arctic edge of Eastern Europe, its interaction with the structures of the North Atlantic and the island massifs.

A study was made of the structure of the sedimentary series by the NSP method in a number of regions of the Sea Okhotsk (17th trip of the scientific research ship "Dmitriy Mendeleev").

Deep sea drilling has been carried out jointly with foreign scientists in the Black Sea (42nd trip of the Glomar Challenger). New data were obtained which have great significance for decoding the geological history of the Black Sea, for studying the transformation of organic matter and the formation of gas and oil deposits.

An important scientific and practical achievement is the development and introduction of a procedure for detailed seismic studies of the earth's crust and the upper mantle in the seas and oceans using powerful pneumatic radiators, bottom seismic stations, seismic buoys and towed receivers.

A generalization and joint analysis of the materials from deep seismic sounding have been performed with respect to the basic tectonic structures of the sea floor: the basins, the medial and block ridges, the deep sea trenches, the inland and marginal seas.

Theoretical studies using a computer and experimental studies have been made of the seismic models and the wave fields connected with them in order to solve the problem of the dynamic methods of interpreting seismic data to study the earth's crust and the upper mantle (jointly with the Leningrad State University and the Siberian Department of the USSR Academy of Sciences).

Geomagnetic Research

Models of the processes occurring at the structural boundaries of the lithospheric plates have been developed which explain the basic laws of the bottom relief, the magnetic anomalies and the gravitational field. A model has been proposed for the formation of the oceanic magnetically active layer permitting explanation of the peculiarities of the fine structure of the magnetic anomalies.

A procedure has been developed for interpretation of the geomagnetic data, and on the basis of it, and also considering the results of the paleomagnetic studies, paleogeographic reconstructions of a number of regions of the world ocean have been performed which will permit new explanation of the nature of a number of large volcanic structures of the sea floor.

A new towed proton magnetometer which provides high accuracy and speed of measurement has been developed and introduced into practice. New models

of towed magnetometers have been introduced into practice, including component and differential magnetometers.

A procedure has been developed for operative data processing on a shipboard computer which will permit a sharp increase in the speed and reliability of interpreting the data obtained; it will permit complex analysis of the magnetometric and other geophysical data. A procedure has also been developed for analyzing the fine structure of the magnetic anomalies insuring that qualitatively new information will be obtained about the magnetic nonuniformity of the oceanic earth's crust.

A series of experiments have been performed with respect to analyzing the relation between the magnetic properties of the coastal rock of the ocean floor and the structure of the magnetic anomalies. Accordingly, the contribution of various rock to the formation of the linear oceanic magnetic anomalies has been established.

A series of experiments have been performed with respect to the generalization of the quantitative characteristics of the magnetic anomalies of the world ocean which made it possible to discover previously unknown laws of the relation of these characteristics to the structure of the bottom and the earth's crust of the ocean.

A procedure has been developed for interpreting the results of the component magnetic surveys which will permit paleomagnetic studies of the oceanic earth's crust and obtaining of qualitatively new data on the sources of the magnetic anomalies.

Magnetic surveys of various parts of the world ocean and also the inland seas of the USSR have been performed in large volume. A large volume of geological-geophysical and magnetic experiments have been performed on Lake Baykal which is part of the active rift zone. A component magnetic survey was performed for the first time in the lake which made it possible to study the nature of the magnetic anomalies of the rift zone in more detail. New data have been obtained on the structure and tectonics of the Baykal basin.

Geomorphology and Tectonics of the Ocean Floor

A united legend has been developed for geomorphological mapping of the ocean floor based on a mapping procedure which is analytical with respect to form but synthetic with respect to content, in which both the large and small forms of relief are indicated by combinations of symbols of the elements of the relief bounding them (slopes, scarps, horizontal and subhorizontal surfaces of different genesis and age). The geomorphological map of the bottom of the Atlantic Ocean on a 1:25,000,000 scale has been compiled in the symbols of the legend, and maps of individual sections of the Midatlantic ridge on a scale of 1:1,000,000, 1:200,000 and 1:40,000 have been compiled by the data gathered by the expeditions under the famous program.

A study has been made of the interrelations of the ocean structures with the tectonic zones of the continent in the transitional zone of the northwestern part of the Indian Ocean and the ophiolitic belts of the Middleeast.

During these years new data were obtained on the geomorphology of the bottom of the Australian-New Zealand region, the western and southeastern parts of the Pacific Ocean. The Kurchatov fault was discovered and mapped here, and a detailed study was made of the Khizen faults and the Macquarie Trench.

New data were obtained in 1976 on the variety of geomorphological provinces of the East Indian rise and the complex dismemberment of its surface.

In the summer of 1977 geomorphological studies were made of the Baykal Lake basin. A physiographic map of the lake basin and bathymetric maps of the test areas were compiled.

Geology of the Ocean

The work has been continued to study the general laws of sediment formation in the world ocean, which, in particular, has found reflection in the monograph "Geology of the Ocean." Maps of the bottom sediments of three oceans have been published. Significant progress has been made in the field of studying ancient sedimentary and volcanogenic-sedimentary rock denuded at the bottom of the oceans. Studies have been made of various shows of hydrothermal mineralization of the sediments in the rift canyons of the media in ridges and in the fracture zones.

New data have been obtained on the relation of magmatism to the tectonic structures of the ocean bed, the rock composition of the second and, in part, the third layers of the oceanic earth's crust. The most interesting information has been obtained in this case in the region of the east Pacific Ocean rise -- in the Hessa basin and in the Eltain fracture zone and also in the system of the Marcus Necker rise, in the Macquarie structural zone and in the fracture zone of the east Indian rise.

A study was made of the biostratigraphy of quaternary and frequent more ancient Cenozoic deposits of a number of regions of the ocean. A new schematic is presented for the zonal distribution of diatoms in the Cenozoic.

The results of many years of studies of the iron-manganese concretions of the Pacific Ocean and phosphorites on the shelves of the world ocean are generalized, the general laws of their distribution are discovered, the problems of their genesis have been developed, and monographs have been published with respect to these useful minerals and also with respect to the geochemistry of uranium in modern marine sediment formation.

It was discovered that the series of large transoceanic faults corresponds to disjunctive latitudinal dislocations on the coasts in the Archean and Proterozoic rock and reactivation of some of the coastal dislocations in the Mesozoic. The tectonic plan of the fracture zones was inherited from

the early phases of geological development. The step nature of the development of the Midatlantic ridge, which was formed as a result of the Cenozoic compression phases and the stepped development of the large faults and the entire ocean as a whole have been traced. The tectonic phases are synchronous to the compression phases of the ground orogenic belts and correspond to the steppes of retardation or cessation of spreading; thus, the Eocene and Miocene tectonic phases coincide with the beginning and end of the spreading age to the north from 53° north latitude and correspond to the steppes in the formation of the North Atlantic structure manifested by local mismatches. The detection of the Eocene limestones in the axial zone of the median ridge permits the proposition of the existence of ancient blocks structurally connected with the transoceanic faults. At the intersection of the latter with the young and ancient submeridional ridges, the existence of structural nodes which are distinguished by their morphology, geophysical characteristics and magmatism is established.

The presence of metamorphic rock of the epidote-amphibolite facies was established in the ocean crust for the first time, and a complete series of facies of regional metamorphism was in practice isolated. The metamorphic rock of the ophiolitic section of the Midatlantic ridge is the product of regional metamorphism of a sodium profile. Debasification is characteristic for the metabasites.

The study of the distribution in the ocean and sea sediments of tungsten and molybdenum made it possible to note their geochemical system.

A method paleothermal analysis of the Quaternary sediments with respect to the shells of Plankton foraminifers has been developed. Accordingly, a study was made of the paleotemperature distribution of the Atlantic Ocean during the course of the basic phases of the Late Pleistocene -- the periods of glaciation, Interstadial and interglacial. Accordingly, the position of the basic water masses, the frontal zones, and currents was reconstructed, and the history of the upwellings was traced.

Evidence was obtained of the block structure of the earth's crust in the Mediterranean megabasin in its heterogeneity. It was discovered that the basins of the Mediterranean Sea belong to the basic category of geostructures (pelagogenic), and they are developed on the submerged edges of the ancient platforms.

Essentially new aspects of the geological structure of the Black Sea basin were discovered when analyzing the composition and age of the basement rock uplifted from the slopes of the Black Sea. Along with continuation of the structures of the western Caucasus, the Crimea and Pont into the slope zone, it was possible to isolate an extended belt of late Cretaceous andesite volcanism from the Balkans in the west to Cape Caucasus (Adzharia-Trialet) in the east running along the Anatolian slope.

Sharp stoping of the Black Sea basin at the beginning of the Pliocene and the formation of it approximately at the modern boundaries was established by the geological-geophysical materials.

Dynamics of the Contact Zone of the Ocean

The concentration distribution laws for the suspended material along the vertical and also the extent of the water in the upper part of the shelf were discovered. Results were obtained with respect to determining the absolute values of the concentration of the suspensions in various horizons of the series during a storm, and the paths of transmission from the distribution of the relative concentrations of the suspended matter to the distribution of absolute values and to the calculation of the consumption of suspended material under storm conditions were noted.

As a result of the analysis abundant field material with respect to wave velocities and their pulsations and also with respect to the currents in the upper part of the shelf, the basic laws of transformation of the wave and unidirectional water currents in the shallows were discovered.

A study was made of the distribution of the transport velocities in the wave field of the shallows along the vertical and the extent of the water series. An analysis was made of the frequency spectrum of the pulsation of these velocities, and the long-period fluctuations were discovered.

On the basis of the developed method of lithodynamic analysis of the sediments by accumulation of useful signals contained in their properties, an analysis was made of the genesis of marine sediments for a large number of regions of the world ocean, both for the shelf sediments and for great depths.

MARINE HYDROPHYSICS INSTITUTE OF THE UKRAINIAN SSR ACADEMY OF SCIENCES

The basic scientific areas of the MGI [Marine Hydrophysics Institute] of the Ukrainian SSR Academy of Sciences in 1975-1978 were the basic and applied research in the field of ocean physics:

The theoretical and experimental studies of the large-scale circulation of the water of the world ocean;

The study of the process of the interaction of the ocean and atmosphere;

The development of the theory and performance of experiments to study the surface and the internal waves;

The study of ocean turbulence within the limits of the meso and microscales.

Along with the traditional areas of geophysical research, in recent years the institute has developed theoretically new areas of hydrophysical research connected with the development of theoretical and experimental principles of satellite oceanography, the creation of the methods and means of systematic study of the physical processes in the ocean.

The institute performed marine expeditionary investigations in the various parts of the world ocean and the ships "Akademik Vernadskiy," "Mikhail Lomonosov" and in the Black Sea on the expeditionary ship "Muksun."

In the process of theoretical and experimental studies performed by the MGI of the Ukrainian SSR Academy of Sciences scientific results of great importance were obtained by the institute with respect to the basic problems of modern oceanology. These results made a significant contribution to the development of the thermohydrodynamic model of the world ocean. Such a model and its fragments will permit description of the dynamic processes in the ocean, beginning with the system of currents on a planetary scale and ending with capillary waves on the surface of the water and small-scale turbulence, and it also makes it possible to forecast all these phenomena with defined lead time.

The institute has also solved a number of basic problems with respect to the most important problems of modern physical oceanography -- the construction of a united model of circulation of the ocean and atmosphere considering numerous and varied processes of interaction between them.

The theoretical new results obtained by the MGI of the Ukrainian SSR Academy of Sciences when studying the large scale (synoptic, year-round and inter-year) of variability of the hydrophysical fields and the dynamics of the ocean water in an exact numerical estimate which is already needed now by navigation, fishing and the practice of long-range meteorological forecasting.

The theory on methods of computer calculation of quasistationary currents in various parts of the world ocean (the south and tropical Atlantic, Caribbean, Black and Azov Seas) have been developed, hydrodynamic models of a number of ocean regions and marginal semiclosed sea basins have been constructed, the basic physical factors and the physical mechanism of the generation of tropical hurricanes have been defined; the elements of the theory have been formulated, and methods of calculating and predicting wave processes, in particular, the tsunami type waves have been created. Studies have been made of the propagation of nonsteady waves generated by periodic atmospheric disturbances operating over a bounded region of the stratified ocean. A study was made of the dependence of the amplitude of the individual internal waves on the form of the pressure region and the nature of the distribution.

Numerical experiments have been performed with respect to analyzing the steady surface and internal gravity waves generated by disturbance of the atmospheric pressure in the stratified ocean in the presence of currents with a velocity shift.

On the basis of the method developed at the institute for calculating the tsunami type waves, the magnitudes of maximum possible upwellings of water were determined for 77 points of the Pacific coast of the USSR. An atlas of maximum possible upwelling of water was prepared and printed for these points as a function of the energy (the magnitude) and the position of an earthquake center. The atlas can be recommended for practical use for purposes of tsunami regionalization and also in the operative tsunami warning service.

A study has been made of the energy balance in the ocean-atmosphere system, procedures have been proposed for operative estimation of it for the world ocean on the basis of the processing of information from the meteorological satellites of the earth. A study was made of the diurnal behavior of short-wave radiation of the oceans, and an experimental basis is presented for the method of calculating it under actual conditions of transparency of the atmosphere and cloudiness and also the diurnal behavior of the characteristics of the aerosol turbidity of the atmosphere by the materials of the international Tropex-74 program. On the basis of the theoretical studies of the determination of the characteristics of aerosol turbidity of the atmosphere, a procedure has been developed for monitoring air pollution.

Studies have been made of ocean turbulence in the meso and microscale regions. Quantitative parameters are defined which characterize the synchronous variability of the quasistationary velocity vector and the elements of the mesoscale structure of the pulsation velocity field under various hydrometeorological conditions for certain parts of the Atlantic, Pacific and Indian Oceans. Studies have been made of the structural characteristics of the pulsation movements in the ocean in the region of short internal wave scales. Quantitative and qualitative estimates were obtained for the parameters of the processes of the generation of short-period internal waves as a function of the nature of the hydrodynamic instability of the ocean water.

In order to develop the principles of remote sounding of the ocean, theoretical studies of the peculiarities of the propagation of coherent optical radiation in the sea have been realized, and a method has been developed for direct simulation of the conditions of propagation of laser radiation considering the reflecting properties of the sea environment under various hydrometeorological conditions. A theory of the calculation of effective and optimal radiation patterns for the sensors of remote noncontact instruments has been developed for specific hydrophysical fields. A procedure has been created which provides for the isolation of the hydrophysical information from the set of data from complex satellite measurements.

On the basis of the data obtained on the expeditionary troops of the scientific research ships, studies have been made of the structure and the time-space variability of the basic hydrophysical and hydrochemical fields of various parts of the world ocean. The peculiarities of the three-dimensional microstructure and the elements of the microstructure of the velocity field, the temperature and salinity distribution have been defined, and the statistical characteristics of the wave elements and energy spectra of the waves have been obtained. The physical laws have been investigated causing the light field in the ocean at various depths and in various parts of the spectrum.

By the results of the complex international joint studies in the tropical Atlantic participated in by the MGI Institute of the Ukrainian SSR Academy of Sciences, the institute prepared more than 500 maps of the international atlas of hydrologic, hydrochemical characteristics, which is published in two volumes by the international oceanographic commission of UNESCO. These maps make up about 90% of the atlas. The editor of the atlas was academician of the Ukrainian SSR Academy of Sciences A. G. Kolesnikov. (The second volume of the atlas on the distribution of the hydrochemical characteristics of the water of the tropical Atlantic was published by UNESCO in 1976.)

On the basis of a systematic analysis of the hydrophysical processes, a dynamic-stochastic model of forecasting the density and current fields for individual regions of the world ocean using expeditionary data was developed, and a forecast was made of the density and current fields with a lead time of 25 days for parts of the North Atlantic and the Gulf of Lion.

Significant attention has been at the institute to the problems of the intensification of the work of automation of hydrophysical research, the creation of new means and techniques for systematic experiments in the ocean; improvement of the modern methods of processing the results of oceanographic observations. Instruments have been created for determining the temperature, the salinity, the velocity and the direction of currents, various optical and acoustic characteristics of seawater, the content of certain chemical elements and radioactive isotopes in it and also specialized devices for remote measurement of some of the physical parameters of the ocean surface. The development of automated systems for performing hydrophysical research is being realized in the direction of creating complex multichannel equipment, the means of transmitting, processing and analyzing observation data, including satellite data.

A large volume of work has been performed by the institute within the framework of international cooperation. Thus, during the course of the Soviet-American POLYMODE program the institute investigated the peculiarities of the mesoscale dynamics of the ocean. As a result of the performed analysis of the dynamic and energy structure of the synoptic eddy fields of the ocean, a model of the evolution of the intensive isolated eddy formations of large scales and a model describing the mechanism of hydrophysical processes occurring in the quasithermal layer of the ocean on passage of deep synoptic eddies were constructed. Using the dynamic-stochastic model with successive assimilation of the data, the initial density field of the test area was calculated in accordance with the POLYMODE program, and its statistical characteristics were estimated. In executing the POLYMODE program, the MGI Institute of the Ukrainian SSR Academy of Sciences has now carried out seven large expeditions to the "Bermuda Triangle" area during the course of which unique observation data were obtained.

The generalized materials of the research under the POLYMODE program have been published in two collections of the Works of Moscow Hydrophysics Institute of the Ukrainian SSR Academy of Sciences.

During the course of the joint Soviet-French studies of the processes of the interaction of the ocean and the atmosphere (the Mediterranean Sea), the institute obtained a broad mass of data for calculating the heat and momentum fluxes on small and medium scales. On the basis of the systematic principles of the organization of the expeditions in 1976 developed at the institute, the second Soviet-French expedition was realized in the Gulf of Lion, in which the scientific research ship "Akademik Vernadskiy" participated on the Soviet side, and on the French side, the floating laboratory buoy "Bora-II" and the scientific research ship "Syurua." During the course of the expeditions all the required data were obtained for computer calculation of the mass of the basic hydrophysical characteristics of the region taking into account the effect of strong local winds (the mistrals). It was in these calculations that the dynamic-stochastic approach to the study of the phenomena in the ocean developed at the institute was first realized, which makes it possible to forecast the processes in the ocean by the observation data.

The results of the studies under the "Sovfrance" program are published in an thematic collection of Works of the Marine Hydrophysics Institute of the Ukrainian SSR Academy of Sciences published in Russian and English, and they were comprehensively discussed at the Second Soviet-French Symposium on the Problem of the Interaction of the Ocean and Atmosphere held in April 1978.

The institute is participating actively in the marine part of the long-range, large-scale international program to study the global atmospheric processes realized by the oceanographic and hydrometeorological organizations of many countries -- ATEP, GARP, JASIN.

The Marine Hydrophysics Institute has performed complex hydrophysical and hydrochemical studies within the framework of the international MOCARIB program encompassing the American Mediterranean [the Caribbean Sea]. The maps of the horizontal and vertical components of the steady currents of the Caribbean Sea were constructed, new characteristic features of the water circulation of this region were discovered, and a study was made of the variability of the fields of the hydrologic elements in the Caribbean Sea and the Gulf of Mexico. A map of the thickness of sedimentary deposits in the Caribbean Sea was compiled on a 1:4,000,000 scale.

The results of the performed studies within the framework of the MOCARIB program were generalized in a monograph prepared for publication.

STATE OCEANOGRAPHIC INSTITUTE

In 1975-1978 the scientific activity of the State Oceanographic Institute (GOIN) was aimed at studying the processes occurring in the ocean, their interaction, the interrelation to the atmosphere and the effect on the formation of the structure and variability of the oceanographic fields on various time-space scales and under various physical-geographic conditions and also the establishment of more reliable quantitative estimates of the characteristics, the functions and the calculated parameters required for solution of theoretical problems and practical use.

The basic studies of this period were connected with studying the central and tropical parts of the Atlantic Ocean. As a result of the studies that were performed, new data were obtained on the variability of the oceanographic fields in the tropical and equatorial zones of the Atlantic Ocean and also in other parts of the world ocean. The laws and the peculiarities of the wind field of the trade winds zone and its variability in connection with the anomalies of the position of the northeast trade winds and the subtropical anticyclones were established.

New data were obtained on the time-space distribution of the external heat budget of the surface of the ocean in the tropical Atlantic in connection with the position of the Intratropical Convergence Zone. The relations of the external heat budget to the heat content of the upper layer of the ocean were found. The time-space stability of its monthly anomalies was determined.

New peculiarities were established in the law of the structure of the water of the tropical zone of the Atlantic Ocean and the fields of the hydrologic characteristics of their variability and the interrelation with some of the defining factors.

A study was made of the basic laws of variability of the atmospheric circulation in the central Atlantic, the formation of the tropical structure of the active layer of the ocean in connection with the variability of the heat budget of the ocean surface and seasonal variability of the drift circulation of the water in the central Atlantic.

A study was made of different scales of variability of the velocities and flow rates of water of the basic currents of the equatorial and tropical Atlantic, including the Gulf Stream. The presence of energy-bearing disturbances with periods of 4 and 8 days and also 0.5, 1.0, 1.5 and about 4 months was demonstrated (in the Gulf Stream with periods close to 3.7, 8 and 13.3 months). The indicated fluctuations have a significant influence on the fluctuations of the oceanographic characteristics. The presence of a relation between the fluctuations of the velocity of the Lomonosov current and the behavior of the air and water temperature on the surface of the ocean was discovered.

The maps of the temperature anomalies of the water on the surface of the northwestern part of the Atlantic Ocean were constructed. During the 1966-1974 period, positive anomalies predominated over the greater part of the water. The negative anomalies were noted directly north of the Gulf Stream and only in the spring months.

The laws and quantitative estimates of the seasonable variability of the physical structure of the water were established, the standard curves were constructed for the vertical temperature distribution of the water of the upper layer of the ocean which serve as identifiers of the water masses and the transition zones.

Estimates were obtained for the magnitudes of the temperature anomalies of the water in the transatlantic section through 36° north latitude and in the Faeroe-Shetland strait.

Studies were made of the laws and estimates of the seasonal interyear variability of the flow rate of water, heat and salt in the basic sections of the northern anticyclonic circulation and the water distribution of the Gulf Stream throughout the central and north Atlantic. Regions were discovered in which the formation of the heat content anomalies of the water in the upper layer of the ocean takes place under the defining effect of advection.

Maps of the average monthly position of the front and the core of the Gulf Stream and also new maps of the average monthly water temperature on the surface of the northwestern part of the Atlantic Ocean were constructed. Typical synoptic situations were defined in which significant deviations of the position of the Gulf Stream take place.

The block diagram depicting the mechanism and the laws of formation of the variability of the oceanographic characteristics was constructed. The basic laws, the paths and the factors of the formation of the temperature variability of the water in the tropical Atlantic were established, and its statistical estimates, the spectra and peculiarities in the various time-space scales and under the regime conditions were obtained.

The scientific basis is presented for creating a United Global System of Ocean Stations (OGSOS). A method has been developed for calculating a

network of buoy stations in the ocean, and a data gathering system is presented. The temperature fields in the various parts of the ocean were obtained.

A method has been developed for calculating the swelling waves based on numerical integration of the equation of the wave energy balance in spectral form permitting calculation of the probability characteristics of the waves under nonstationary and nonuniform conditions of wave formation.

A study was made of the petroleum product and detergent pollution of the surface microlayer of certain parts of the north Atlantic. A significant increase in concentration of pollutants in it was demonstrated by comparison with the upper one-meter layer which influences the processes of moisture, gas and heat exchange with the atmosphere.

The basic expeditionary work of the institute was aimed at providing for observations in accordance with the international WMO program at ocean station Charley and the performance of research in the standard sections of the DIGMA program.

ARCTIC AND ANTARCTIC SCIENTIFIC RESEARCH INSTITUTE

The oceanological studies of the Arctic and Antarctic Scientific Research Institute in 1975-1978 were aimed at studying the interaction of the ocean and the atmosphere and the loss of formation of the hydrometeorological conditions in polar regions. The studies were performed in accordance with the long range national programs of the Polar Experiment (POLEX-NORTH and POLEX-SOUTH) which is a component part of the global atmospheric research program (GARP).

The polar regions are the basic energy drainage regions. Therefore one of the main goals of the Polar Experiment consists in quantitative estimation of the role of the atmosphere and ocean in the formation of their energy balance. In addition, the POLEX program includes a number of important problems connected with the problems of large-scale interaction of the ocean and atmosphere in the polar regions and study of the mechanisms which form the long-period variations of the hydrometeorological processes in the Arctic and Antarctic. The resolution of these problems has general scientific significance and corresponds to the urgent requirements of practice. The performance of theoretical and field studies was provided for in two parts of the earth north of 50° north latitude and south of 50° south latitude.

Arctic Ocean

1. Large-Scale National Field Experiment POLEX-NORTH-76 (April-August 1976).

By the experimental results most completely processed for the northern European basin, quantitative estimates were obtained for the heat balance components of the atmosphere-ocean system which permits the following preliminary conclusions to be drawn.

During the spring (May-June), that is, even during the period of maximum influx of solar radiation, the transport in the ocean turns out to be a more important factor in the formation of the thermal conditions of the atmosphere.

The advection of heat by the currents is one of the main sources of heat carried by the fluxes in the atmosphere to the east and northeast, including the boundaries of the European territory of the Soviet Union.

The heat accumulation in the ocean turned out to be of the same order and the radiation balance and advection of heat by the currents, that is, during the fall and winter months the amount of oceanological heat delivered by the currents can exceed by several times the amount of heat coming into the atmosphere from other sources, including the sun.

Thus, when developing the long-range meteorological forecasts for the northern polar region and the European territory of the USSR, the advection of heat by the current must be considered as one of the main factors forming the weather conditions.

2. Results of Theoretical Studies and Regular Hydrologic Surveys of the Arctic Ocean

Experimental substantiation was obtained for the principle that drift ice can be considered as a solid medium, using the known differential equations of the continuous model for the description of its movement. The possible significance of this least spatial scale was demonstrated, beginning with which the indicated equations acquire their force.

The numerical methods of calculating the steady state barotropic currents have been developed which are used to calculate the currents of the individual parts of seas of small and medium depth.

By the complex analysis of the hydrometeorological data and more precise definition of the method of oceanographic leveling it has been established that the rates of modern vertical movements of the shorelines of the Arctic seas are appreciably less than the estimates available up to now and for the majority of points of observation of sea level they do not exceed the errors of their calculation by the oceanographic method.

It has been established that the basic factors shaping the density field of the water of the Arctic basin are the preceding and summer atmospheric processes and the fluctuations of the water exchange of the Arctic Ocean with the adjacent parts of the Atlantic and Pacific Oceans. The dynamics of the surface water of the Arctic basin are quite closely connected with the iciness of the Arctic seas and the generalized circulation indexes of the water can be used as predictors when forecasting the perennial fluctuations of the iciness with a lead time of more than a year.

In the fluctuations of the intensity of the anticyclonic circulation in the Arctic basin, the presence of a quasiseven year cycle has been established. These fluctuations in intensity are manifested both directly in the growth or fall of the dynamic altitudes and, correspondingly, in the variation of the area encompassed by the periphery of the anticyclonic circulation, which has a significant influence on the ice conditions of the

seas of the eastern sector of the Arctic. During the years with intensive anticyclonic circulation of the water in the Arctic basin periphery of the anticyclonic circulation encompasses the marginal seas, which promotes removal of the perennial ice and a shift of the edge of the ice to the north. A decrease in the intensity and a reduction in area encompassed by the circulation leads to the development of cyclonic type circulation in the marginal seas, and the edge of the ice is located on the average 5 to 6° south with respect to latitude.

The role of the Atlantic water in the heat balance of the Arctic Ocean has been more precisely defined. The fluctuations of the heat content of the Atlantic water from year to year turned out to be so significant that the previously existing opinion of small variations in the thermal state of the deep water in the Arctic basin and the concept of "conservatism" of the hydrologic regime of the Arctic basin based on it are in need of reexamination.

The balance model of the Arctic Ocean has been developed taking into account the basic factors influencing the formation of large anomalies of the ice-hydrologic regime: advection of the heat by the currents, water exchange with the adjacent oceans (considering the effect of the fluctuations of the fresh water runoff), the wind and baric conditions, the packing of the ice, the heat fluxes from the ocean through the ice. The model opens up the possibility of determining the climatic variations in the ocean by the given variations of the influencing factors.

It has been established that the introduction of the predictors taking into account the oceanological conditions of the Arctic Ocean and the bounding regions of the Atlantic and Pacific Oceans into the forecasting relations is giving promising results. This approach appears to be especially prospective when developing the procedure for background ice-hydrologic forecasts with long lead time. A procedure has been created for long-range ice-hydrologic forecasting based on consideration of the large-scale ocean and heliophysical factors.

An analysis has been made of the perennial fluctuations of the thermohalinic state of the waters of the Faeroe-Shetland trench, indicating the presence of the relation between the heat content of the Atlantic water in the trench and the iciness of the western regions of the Arctic. Quantitative characteristics of the perennial fluctuations of the water and heat exchange in the vicinity of the Faeroe-Shetland strait have been obtained, which to a great extent determine the peculiarities of the hydrologic regime of the Arctic Ocean.

3. Results of the Studies on the Problem of the "Interaction of the Ocean and Atmosphere."

Various versions of the hydrodynamic models of atmospheric circulation have been constructed taking into account the specific nature of the polar region. Numerical experiments have been performed by using a small-parametric model of the atmosphere and the ocean to discover the long-period

thermal interaction of the ocean-atmosphere system, and a geodynamic model has been constructed which describes the large-scale interaction of the ocean and atmosphere.

The energy fluxes in the various latitudinal zones have been estimated, and an atlas of maps of the components of the energy balance of the northern polar region has been prepared. The horizontal heat fluxes in the atmosphere have been calculated, and an analysis of them has been performed.

The hypothesis has been developed which explains the influence of the heat exchange of the ocean with the atmosphere on the development of anomalous weather conditions in Europe.

4. Study of the Role of the Thermohalinic Structure of the Upper Layer of the Ocean in the Stability and the Time Variability of the Marine Ice Cover.

The modern Arctic Sea ice cover is highly resistant to variations of the external climate-forming factors, and the cause of this stability is the peculiarities in the structure of upper layer of the Arctic Ocean, in particular, the presence of a desalinated surface water mass. The variations in area of the Arctic Sea ice cover take place basically as a result of rearrangement of the thermohalinic structure caused by variations in the propagation of the desalinated surface Arctic water.

A hypothesis is proposed regarding the origin of the ice ages of the Pleistocene based on variations in area of propagation of the surface Arctic water as a function of the fresh water balance of the Arctic Ocean developed with time and the phase of development of the land glaciation.

5. Study of the Thermal and the Dynamic Processes in the Ice Cover of the Arctic Seas.

Studies have been made of the small-scale dynamic processes in the most variable edge zone of the Arctic Sea ice cover. The main peculiarities of the structure of the drift fields in this zone have been discovered, the characteristics of the deformation of the ice cover have been established, and the effect of various factors on the dynamics of the sea ice has been discovered. The data obtained have found broad application in the methods of ice forecasting and calculations developed by the institute.

An improved physical-mathematical model of the variation of the state of the ice cover during the summer has been developed in which a number of thermal and dynamic processes having significant influence on the variation in thickness, packing and other characteristics of the ice cover were taken into account for the first time. The most important of them is the mechanism of the gradual breakup of the melting ice, which plays the predominant role in the destruction of the ice cover during the initial period of melting of it. The method based on this procedure used to calculate the ice distribution has been tested and has made it possible to proceed with the development of a numerical method of forecasting the ice distribution in the Arctic seas.

A complex field experiment has been performed to study the thermal and dynamic processes in the ice cover during destruction of it. New (previously unknown or little studied) phenomena and processes have been detected: the effect of the heat content of the water on buildup of ice, the mechanism of contamination of the ice and the influence of this contamination on the subsequent destruction of the ice cover. The expenditures of heat on melting are estimated, and a study is made of the laws of the ice drift and the process of diffusion of the packing in the edge zones.

6. Hydrochemical Studies and the Investigation of the Chemical Pollution of the Arctic Waters.

The modern knowledge of the hydrochemical regime of the Arctic basin and the seas of the Siberian shelf are generalized, and the general laws of the distribution of the hydrochemical elements in the Arctic Ocean are discovered. This has made it possible to use hydrochemical indexes as the reliable indicators in the water masses when solving important problems of polar oceanography.

Recommendations have been developed with respect to the creation of a network of stations observing and monitoring the pollution of the seas of the Siberian shelf.

Quantitative characteristics have been obtained which indicate that in the seas of the Siberian shelf and also in the Norwegian and Greenland Seas the content of petroleum products, detergents and xanthogens is less than the maximum permissible concentration.

7. Atlas of the Arctic Ocean

This atlas is a component part (Volume III) of the basic ocean atlas. The atlas contains quite detailed information about the basic elements of the hydrologic, ice and hydrochemical regimes from the surface to a depth of 5000 meters and also the dynamic processes in the Arctic Ocean. They are presented in various sections and, in particular as follows:

The section on "Hydrology" includes maps of the temperature, salinity and density of the water, the hydrologic sections, fluctuations and level, surface and deep currents, ice conditions, ice drift, and so on;

The section on "Hydrochemistry" gives the spatial distribution on the surface of the ocean and at a depth of the dissolved oxygen, the hydrogen ion, concentration, the distribution of the alkalinity and biogenic elements (phosphates and silicate).

When developing the various sections, along with using the generalized data from direct observations, modern physical-statistical methods of calculation found application.

Antarctic Ocean

The work under the POLEX-SOUTH program in the Antarctic Ocean was started in January-March 1975, and it has been performed within the framework of the Soviet-American cooperation in the study of the world ocean. As the result of the experiments performed in the Antarctic Ocean in 1975-1978, the following was established.

The Antarctic circumpolar current (ACC) has a complex structure. This current is multistream. The velocities of the currents in the streams can reach 100 cm/sec; in individual areas the maximum current velocities are observed at depths of 2000 meters or more.

There is no compensation for the vertical flows of water in the ACC system. The basic flow of the current is quite uniform with respect to the direction from the surface to the depths of 3000 meters. In Drake Passage at depths below 3000 meters a weak countercurrent is detected. The flow of water in the ACC in Drake Passage considering the instrument observations will be about 124 Sv, and at the outlet from the Scotia Sea in the passage through the Southern Antilles threshold, about 50 Sv. These estimates are the most reliable and are used when simulating the circulation of the Antarctic Ocean water.

The defining role in the dynamics of the ACC is played by meandering and eddy formation. On the basis of the instrument data, the role of the meso-scale synoptic and seasonal variability of the current velocities in the ACC system is estimated.

The Antarctic polar front (APF), along with the ACC, is the most important characteristic of the hydrology of Antarctic waters. The APF zone is clearly manifested in the distribution of almost all physical and chemical characteristics of the water masses of the Antarctic Ocean. The sharp vertical delimitation between the cold Antarctic and the warmer subantarctic water detected in the APF zone and also the thickening of the cold layer ahead of the front create significant density gradients in this zone. The latter leads to an increase in the slopes of the level in the front zone and, as a consequence, to intensification of the ACC stream. An important peculiarity of the APF zone is the presence of eddies. They are detected in Drake Passage and the Scotia Sea, in the region between Australia and Antarctica. The dimensions of the eddies are about 60 miles in diameter, and the displacement velocities are 8-10 cm/sec. The average position of the APF zone by observations in Drake Passage and the Scotia Sea is relatively stable. The variability of the boundaries of the zone, just as its latitudinal extent, are connected with the meandering and eddy formation. The boundaries of the APF zone coincide with the position of the basic flows of the ACC water.

Instrument observations in the northwestern part of the sea of Waddell and the Davis Sea demonstrated the existence of regions of sliding of the shelf water along the continental slope of Antarctica, which confirms the

proposition of the possibility of the formation of natural Antarctic water in the regions of the Antarctic Ocean as a result of mixing of the deep Antarctic water with the cold shelf water. The mixing mechanism has not been fully explained, but the presence of internal waves has been discovered, which breaks when they reach the gentle continental slope. Their breaking also obviously creates conditions of mixing of the shelf and deep water masses.

The latest observations in the Antarctic Ocean indicate that in addition to the regions of formation of the bottom water associated with the shelf and the continental slope, the possibility of the formation of natural Antarctic water exists even in the open, deep sea regions with uniform water characteristics and their weak vertical stability. Such regions can be the zone of convergence of the water of the Scotia Sea and the Waddell Sea and also the region of quasistationary ice lead in the northeastern sea of Waddell.

ALL-UNION SCIENTIFIC RESEARCH INSTITUTE OF FISHING AND OCEANOGRAPHY

The materials of the complex expeditionary studies of 1964-1975 in the southeastern part of the Atlantic sector of the Antarctic (Scotia Sea and bounding waters) have been generalized. The characteristics of the thermal regime, the basic circulation peculiarities, their interyear variability in connection with the formation of the biological productivity of the Atlantic waters have been discovered.

In 1975-1978, the expeditionary studies continued in the Antarctic waters (the Atlantic sector -- the Scotia and Waddell Seas, the Pacific Ocean sector -- Bellingshausen Sea and the water adjacent to it on the north). The results of these studies essentially supplement the available information on the hydrologic regime of the waters of the Atlantic sector of the Antarctic. These studies indicated, in particular, the possibility of significant inter-year variations in the structure of the current field of the Scotia Sea and the northern part of the sea of Waddell and the water of the Antarctic circumpolar current in the eastern part of the Scotia Sea.

The broad complex experiments performed in relatively poorly investigated part of the southeastern area of the Pacific sector of the Antarctic have made it possible to obtain a more detailed concept of the nature of the propagation of the water process, the distribution of the physical-chemical characteristics, their influence on the formation of the biological productivity of the water, the distribution of the phytoplankton and zooplankton. A broad zone has been discovered along the continental slope of the Bellingshausen Sea and the Antarctic Peninsula characterized by noticeable disturbances in the current field and the presence of circulations. The formation of this zone identified with the Antarctic divergence is connected not with the anemobaric conditions as was previously assumed, but with the upwelling of water along the steep continental slope.

In the theoretical research plan with respect to the average perennial density field in 1975-1978, numerical diagnostic calculations were made of the currents of the western part of the Atlantic sector of the Antarctic, the Scotia Sea, and the nature of the mesoscale meandering of the zone of interaction of the waters of the sea of Waddell and the Antarctic circumpolar current was investigated. It was demonstrated that the basic bends of the

Antarctic circumpolar current in the Scotia Sea are caused by the bottom relief; the characteristic meanders of the interaction of the water of the sea of Waddell and the Antarctic circumpolar current are inertial-topographic, and quite noticeable fluctuations of this zone in the eastern part of the Scotia Sea are a consequence of the joint effect of the bottom relief on the baroclinic instability of the density field.

In the example of the North Atlantic a study was made of the oceanographic conditions forming the space and time nonuniformity of the bioproductivity of the water. The parameters of the biological productivity reveal the best relations to the distribution of the horizontal and vertical density gradients of the seawater.

The problem of "Chemical Basis for Bioproductivity of the Ocean" was resolved for the first time for the ocean (in the example of the Indian Ocean). The generalization of a large quantity of data from the expeditionary observations (more than 100,000 chemical analyses) made it possible to present an estimate of the reserve of nutritive salts by layers and for the ocean as a whole, their balance and cycle. The zones of different degree of provision with nutritive salts were isolated, permitting estimation of the potential bioproduction possibilities of the Indian ocean. The role of various factors in the equipment of the photic layer with biogenic elements and their role in feeding the phytoplankton were established quantitatively.

The N/P and Si/P ratios characterizing the intensity and the direction of the biogeochemical processes were calculated and mapped for the first time on the scale of the ocean; the laws of their spatial propagation were also discovered. The limiting role of the nitrogen compounds in the production of the phytoplankton was established, and on the basis of the N/P ratio, the biogeochemical provinces were isolated with a different degree of nitrogen inefficiency in the feeding of the phytoplankton.

The problem of the effectiveness of the use of the nutritive salts with respect to zones of the Indian Ocean determined by the circulation rates of the biogenic elements was solved.

The primary production in the waters of the Indian Ocean based on the reserve of nutritive salts was calculated considering their turnover rate and the duration of the vegetation period; the proportion of the removal of organic material by fishing from the annual magnitude of primary production was determined differentiated by zones and for the ocean as a whole.

In 1976-1977, by contract with the FAO, complex expeditionary studies were performed on the scientific research ship "Violent" and "Professor Mesyatsev" off the west coast of Africa (from 5° north latitude to 17° south latitude) and in the waters of Kenya, Tanzania, Mozambique and also on the banks of the Mascarene rise. The purpose of the oceanographic studies was investigation of the hydrologic regime in the possible fishing areas, the oceanological substantiation of the formation of the biological productivity of the water. The defining role of the upwelling of the water (quasistationary or seasonal nature) in the formation of local zones with relatively increased biological productivity was established.

MOSCOW STATE UNIVERSITY

Studies were performed with respect to four areas:

- a) the exchange processes at the ocean-atmosphere interface and the mechanisms of mixing in the active layer of the ocean;
- b) the study of the effect of the interfaces of different nature on the oceanological processes in connection with the pollution problem;
- c) study of estuary processes;
- d) study of the peculiarities of the large-scale interaction of the ocean and atmosphere in the tropical zone.

The most important theoretical results with respect to the first item include the establishment of the dependence of the roughness parameter of the water surface on the wind velocity and the degree of pollution of the sea surface. Beginning with the energy balance equation at the ocean-atmosphere interface, a theoretical formula was obtained to calculate the roughness parameter, according to which this value is inversely proportional to the wind velocity and the pollution of the sea surface. The surface pollution is felt only for low wind velocities.

When studying the interfaces, the relations to these surfaces to the complex geographic structure of the ocean, its complex physical-geographic regionalization and the processes of transformation of matter and energy were established. A map of the basic physical-geographic regions of the ocean was compiled and published.

The basic results with respect to the division on the "Study of Estuary Processes" were isolation of three types of interaction of the seawater and the river water: river, estuary and sea with special features characteristic only of them.

In the example of the White Sea a study was made of the effect of the river water on the hydrologic structure and the sea conditions with the application of the oxygen isotope analysis. The difference in the isotopic

composition of the continental waters of different sources offers the possibility of delimiting the zone of influence of one source or another.

Finally, the study of the large-scale interaction of the ocean and the atmosphere in the tropical Atlantic region adjacent to northwest Africa made it possible to establish the relation between the variability of the water circulation in this region and the variability of the wind field. It was established that the water circulation and other phenomena connected with upwelling in this region reacts quite quickly with a time scale on the order of several days to the wind field variability. This synoptic variability takes place against a background of seasonal and annual variations.

In 1975-1978, scientific research work was done on the topic of "Investigation of the Formation and Variability of the Hydrologic Conditions of the Seas." The southern seas of the Soviet Union and also the Arabian Sea, the Mediterranean Sea and the sea of Argentina were studied. Annual expeditionary studies are made in the Black Sea. The "Regional Plan for Conservation of the Environment of the Southern Seas" was developed.

In 1977 expeditionary studies were made in the Mediterranean Sea on the scientific research ship "Akademik Petrovskiy" jointly with the USSR Academy of Sciences and the Ukrainian SSR Academy of Sciences, the State Commission on Hydrometeorology and monitoring the environment, and so on within the framework of the interdepartmental expedition by resolution of the State Committee on Science and Engineering of the Council of Ministers of the USSR. As a result, a detailed study was made of the process of the mixing and formation of the water masses of the central basin of the Mediterranean Sea during the winter.

LENINGRAD STATE UNIVERSITY

I. Basic Scientific Problems.

1. Studies of the variability of the oceanological fields and characteristic features of the ocean regime using satellite data.
2. Studies of the structure and the laws of the functioning of the ecosystems of the ocean in order to develop methods of regulating their dynamics.

II. Most Important Results.

A device for input of satellite oceanological information to a computer and a procedure for operative processing of this information by computer have been developed;

A number of procedural problems have been resolved connected with decoding among geographic gridding of television and infrared information received from artificial earth satellites and the use of this information to study oceanological subjects;

A study was made of the dynamics of the frontal zones in the northwestern part of the Pacific Ocean, the mesoscale eddy formations and also the disturbances in the frontal zones caused by typhoons;

The principles of the general theory and the semiempirical methods of calculating the oceanological consequences of the passage of typhoons over the fishing areas of the Pacific Ocean have been developed;

Theoretically new data have been obtained on the peculiarities of the distribution and circulation of sea ice in the southern polar region of the world ocean; it has been established in particular that the stationary nature of the cyclones is not a law, as was considered up to now, and, as a result, the ice can be carried to the north in any region, and its intensity is characterized by very great variability in time and in space.

The "Okean" automated analysis system has been developed which is designed for the solution of a set of information and specialized problems of the

simulation of the time-space structure and the peculiarities of the functioning of the initial elements of the marine ecologic systems:

The problems of the Pacific computer implementation of four of the automated analysis system subsystems have been formulated: the "Marine Ecology" information retrieval system for the automated experimental data processing system, the system for simulating the oceanological complex, the system for simulating the chemical-biological complex;

A series of stationary and nonstationary problems of the water circulation in the barotropic and the baroclinic models of the Baltic and North Seas and also the problem of the simulation of the annual cycle of nitrogen and phosphorus exchange in the spatially uniform and two-layer models of the ecosystems of these seas have been resolved.

LENINGRAD HYDROMETEOROLOGICAL INSTITUTE

In 1975-1978, experimental (in the laboratory and in the sea) and theoretical studies were made of the physical laws of the processes in the active layer of the ocean, and on the basis of this a mathematical model of the formation of the hydrologic regime of the active layer of the ocean was constructed.

Laboratory and field experiments were performed with respect to the study of the thermal structure of the upper layer of the ocean. On the laboratory setup created at the department of oceanology, the process of the formation of the isothermal layer and the temperature discontinuity layer underlying it under the effect of turbulence of shear and diffusion origin was simulated for a heat flux through the surface of the liquid and tangential wind stress variable in time. The performed experiments demonstrated the possibility of the reproduction of the structure of the active layer observed in the ocean under the effect of local mechanisms.

Experimental studies of the thermal structure in the sea were also performed from the scientific research ships of the Leningrad Hydrometeorological Institute "Nerey" and "NIK-1." The primary goal of the experiments was the development of a procedure for performing the experiments and testing the created experimental equipment, in particular, the thermobar.

On the basis of the laboratory and field experiments performed, a mathematical model is formulated for calculating the vertical structure of the active layer of the ocean, taking into account only the local mechanisms (the tangential wind stress, the mass flux through the surface of the ocean and also the shifting nature of the turbulent mixing in the seasonal thermocline).

By the proposed model calculations were made of the seasonal evolution of the thickness of the quasiuniform layer and the vertical temperature distribution and salinity of the water in the active layer of the northern part of the Atlantic Ocean. The calculated climatic picture of the vertical thermohalinic structure agrees satisfactorily with the available generalizations of the data from many years of observations.

In 1975-1978, studies were also made of the dynamic and the thermal interaction of the boundary layers of the atmosphere and ocean. Work was done to study the characteristic features of establishing the conditions at the atmosphere-ocean interface, the peculiarities of the influence of the processes occurring in the wave layer on the structure of the air and water layers adjacent to it. A preliminary model of the calculation of the vertical structure of the upper layer of the ocean and the boundary layer of the atmosphere by the available meteorological data was constructed (either by the forecasting data for the free atmosphere or the ship observation data). The model was used to calculate the characteristics of the turbulence of the upper layer of the ocean for the northern half of the Atlantic Ocean.

Studies were also made of the formation of sea ice as the product of interaction of the atmosphere and ocean. The peculiarities of the freezing of the sea and the propagation of ice on its surface under the effect of thermal and dynamic factors were investigated.

Experiments were performed with respect to the electroanalog simulation of the physical processes in the ocean (the procedure was developed and the results were obtained for electric simulation of long waves, nonsteady state fluctuations in level, wind-driven waves, and sea currents in multiconnected regions).

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